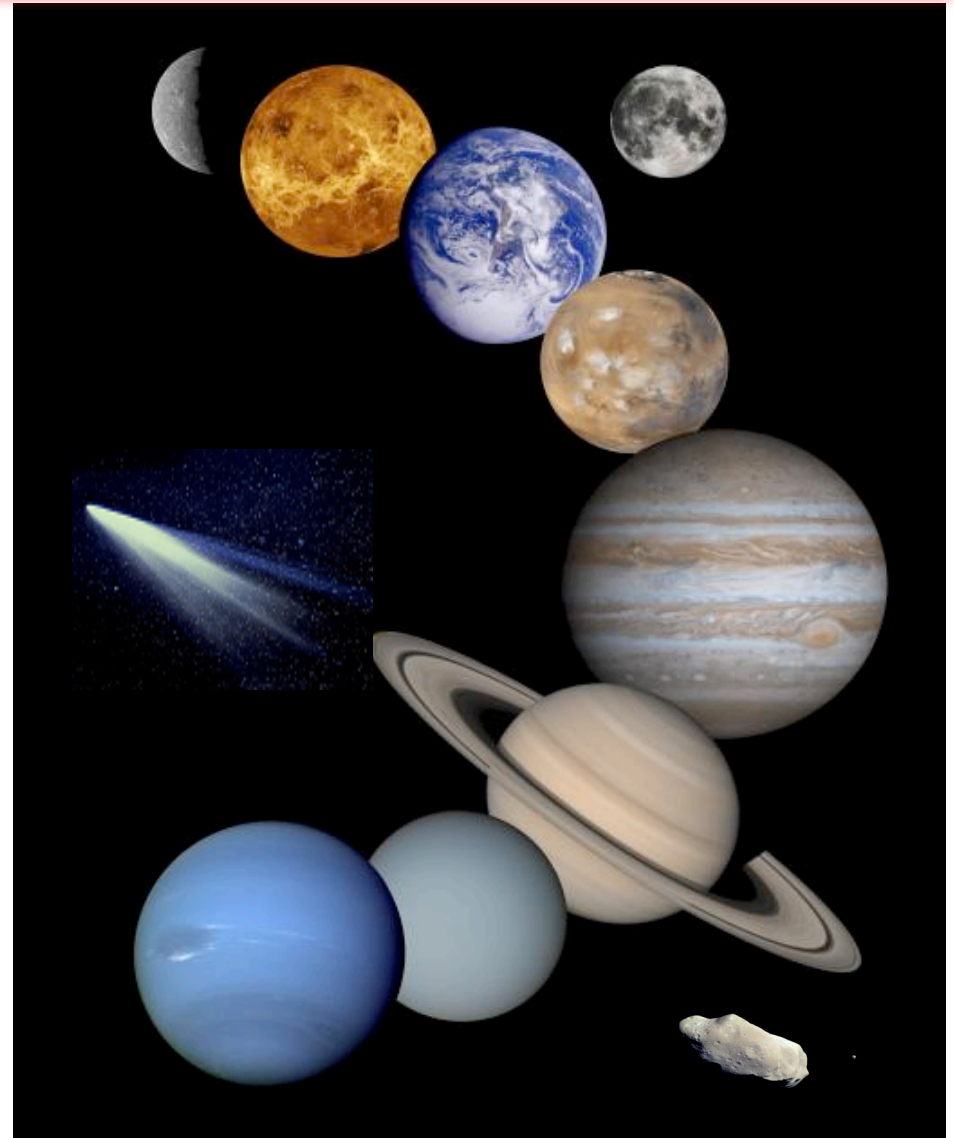




# **TMC Lessons Learned from PI-Led Planetary Science Missions**

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# Agenda

## TMC Lessons Learned

- Background
- Space Science Mission Risks
- TMC Risk Envelope Concept
- TMC Evaluation/Risk Rating
- Lessons Learned Summary
  - Historical Risk Ratings
  - Major Weaknesses per Proposal
  - Common Causes of Major Weaknesses
    - Design Margins
    - Cost and Reserves
    - Instrument Implementation
    - Complex Operations
    - System Engineering
    - Management and Schedule
- Summary
- Questions



# Background

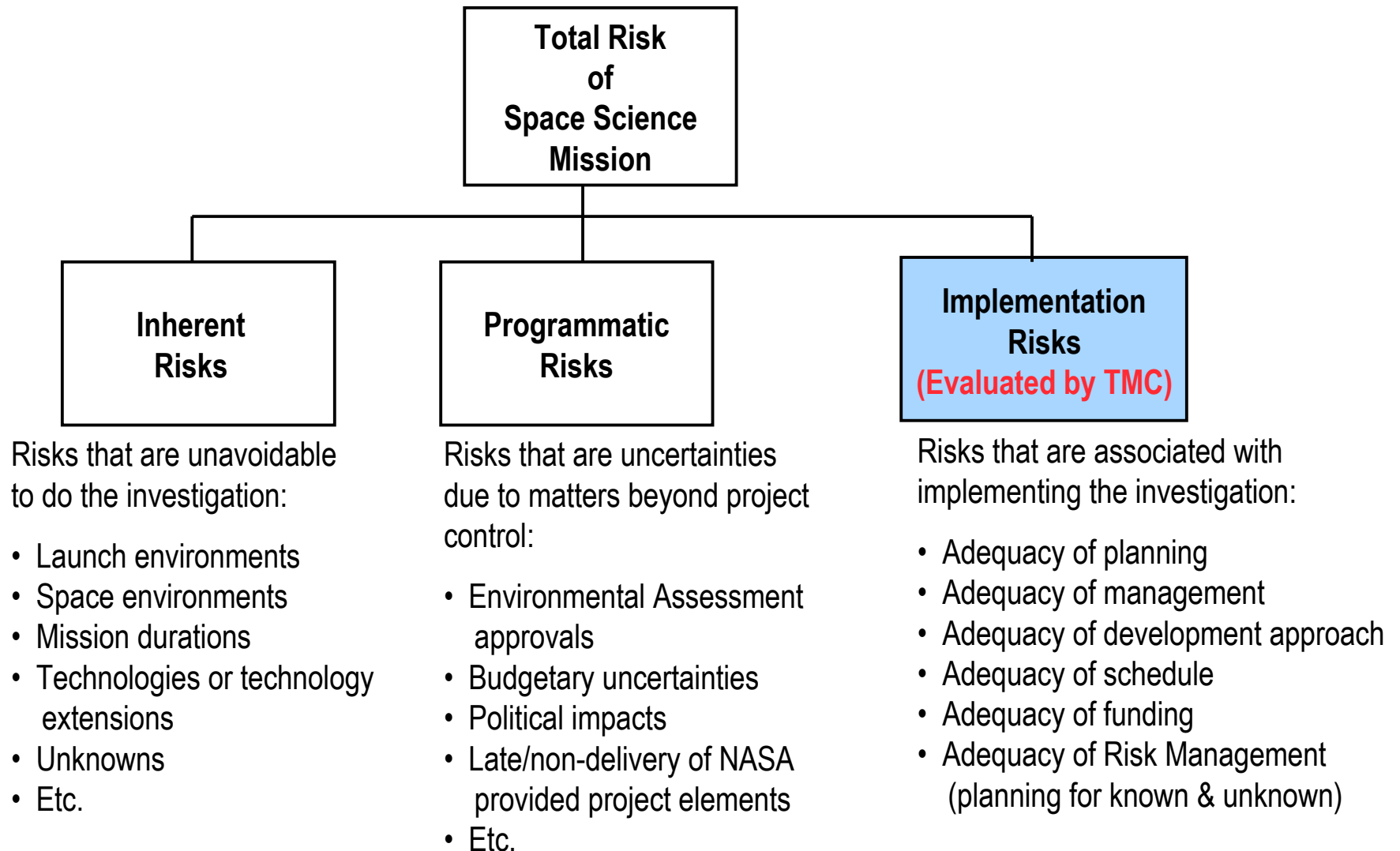
## TMC Lessons Learned

- The Science Support Office (SSO) at LaRC has directed Technical, Management, and Cost Step 1 and Step 2 evaluations of proposals for PI-Led Science Missions for the last 10 years.
- The scope of this Lessons Learned Study only pertains to Step 1 TMC Evaluations of all full mission, science instruments, and missions of opportunity during the period 1996 to 2005. This scope contains a proposal history of 657 proposals.
- The results of this Study identified several lessons that may be valuable to reduce the learning curve for new proposers and to improve the overall quality and maturity of all proposals submitted.
- The purpose of this presentation is to summarize these lessons learned for the benefit of proposers to future NASA Science Mission Directorate AOs for competitively selected earth and space science missions.



# Space Science Mission Risks

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**Lessons Learned**



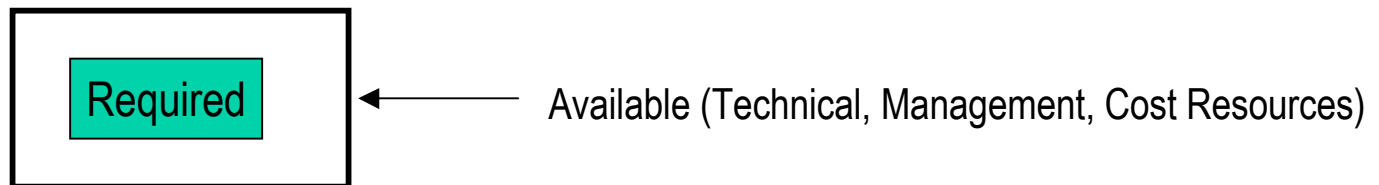


# TMC Risk Envelope Concept

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Lessons Learned

**Envelope:** All TMC Resources available to handle known and unknown development problems that occur.

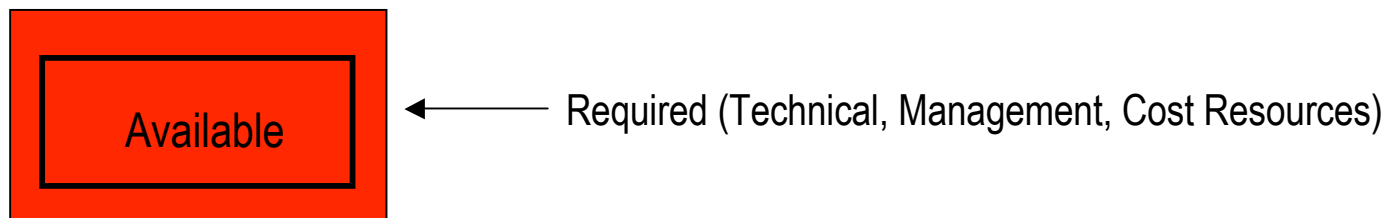
**Low Risk:** Required resources fit well within available resources



**Medium Risk:** Required resources just barely inside available resources.



**High Risk:** Required resources DO NOT fit inside available resources.





# TMC Evaluation/Risk Rating

## TMC Lessons Learned

- The TMC Panel evaluates the feasibility of the proposed approach to mission implementation, including cost.
- This results in a TMC Risk Rating as either High, Medium, or Low.
- The Basic assumption is that the proposer is the expert on their proposal. Therefore, reasonable benefit of the doubt is given to the proposer.
- The proposer's task is to provide evidence that their project is Low Risk. The TMC Evaluation Team's Task is to try to validate the proposer's assertion of Low Risk.
- For Step 1 proposals, the proposal's Risk Rating is driven by the proposal's Major Strengths and Weaknesses. Minor Strengths and Weaknesses are briefed to proposers, but do not impact the Risk Rating. The primary factor that places a proposal in a Medium or High Risk category are Major Weaknesses.
  - The number of Major Weakness is not the sole factor in warranting a higher Risk Rating. Other items considered are: 1) The seriousness of the Major Weakness, and 2) Whether the Major Weakness can be fixed within the cost cap and schedule constraints.
  - One Major Weakness, if serious enough, could warrant a proposal to be judged to be High Risk.



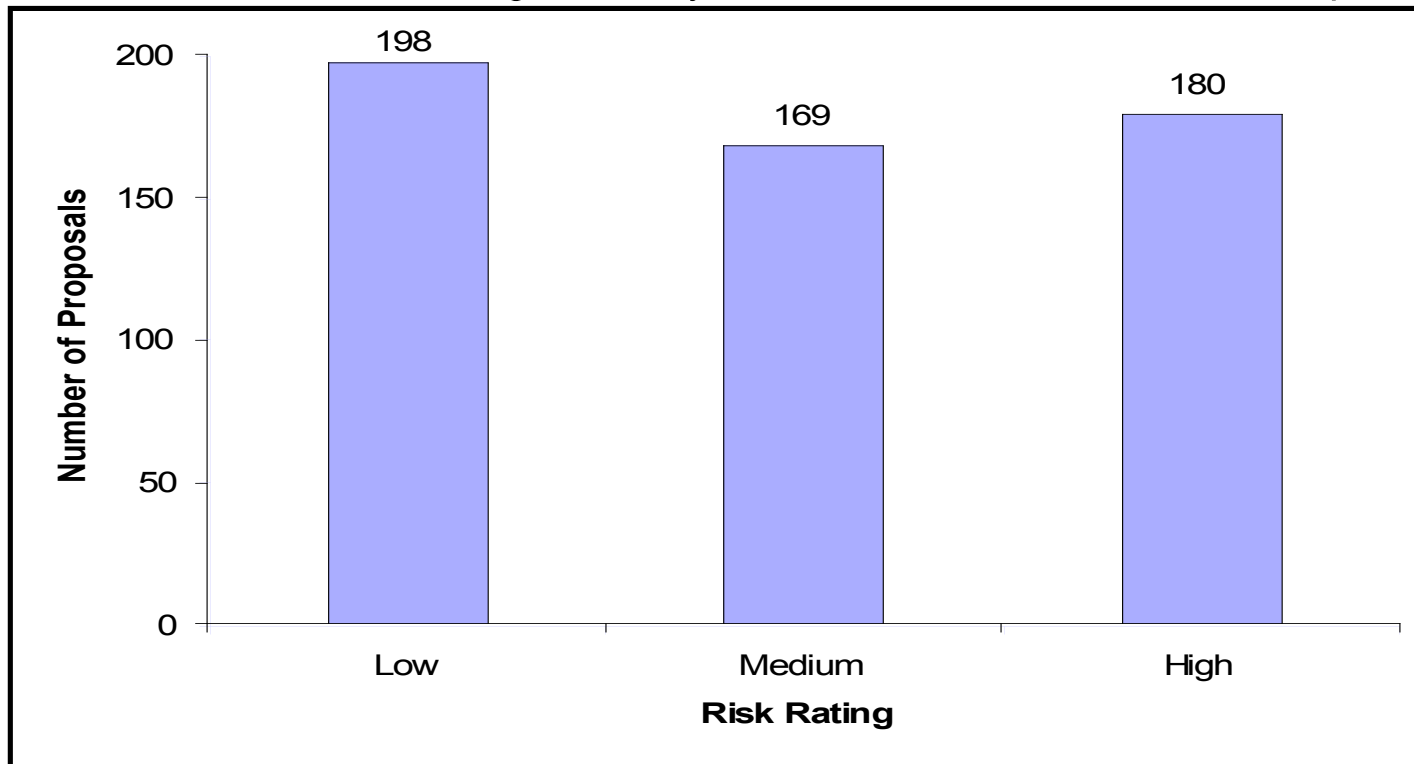
# Lessons Learned Summary

## Historical Risk Ratings

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Lessons Learned

A **Low Risk** proposal is one that TMC reviewers expect will accomplish its goals within the schedule and cost proposed.

- Of the 547 proposals given a Risk Rating, only 198 (36%) received a Low Risk Rating.
- No full missions rated as High Risk by TMC have been selected for implementation.



Summary of Risk Ratings for Step 1 Proposals

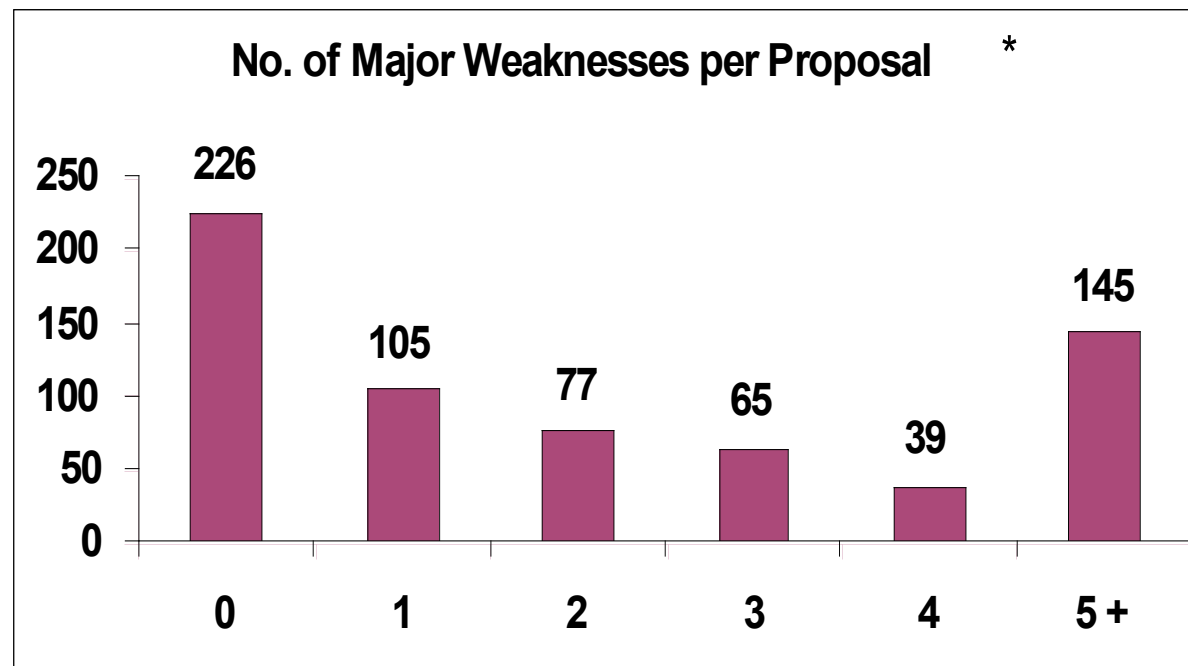


# Lessons Learned Summary

## Major Weaknesses per Proposal

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Lessons Learned

- Only 34% of proposals reviewed were judged to have no Major Weaknesses.
- The number and severity of Major Weaknesses directly affect the overall implementation Risk Rating.



### History of Major Weaknesses per Proposal Evaluated

\* This chart includes 657 proposals. This number is greater than the 547 proposals as noted on the previous slide, since not all evaluations resulted in a TMC Risk Rating.

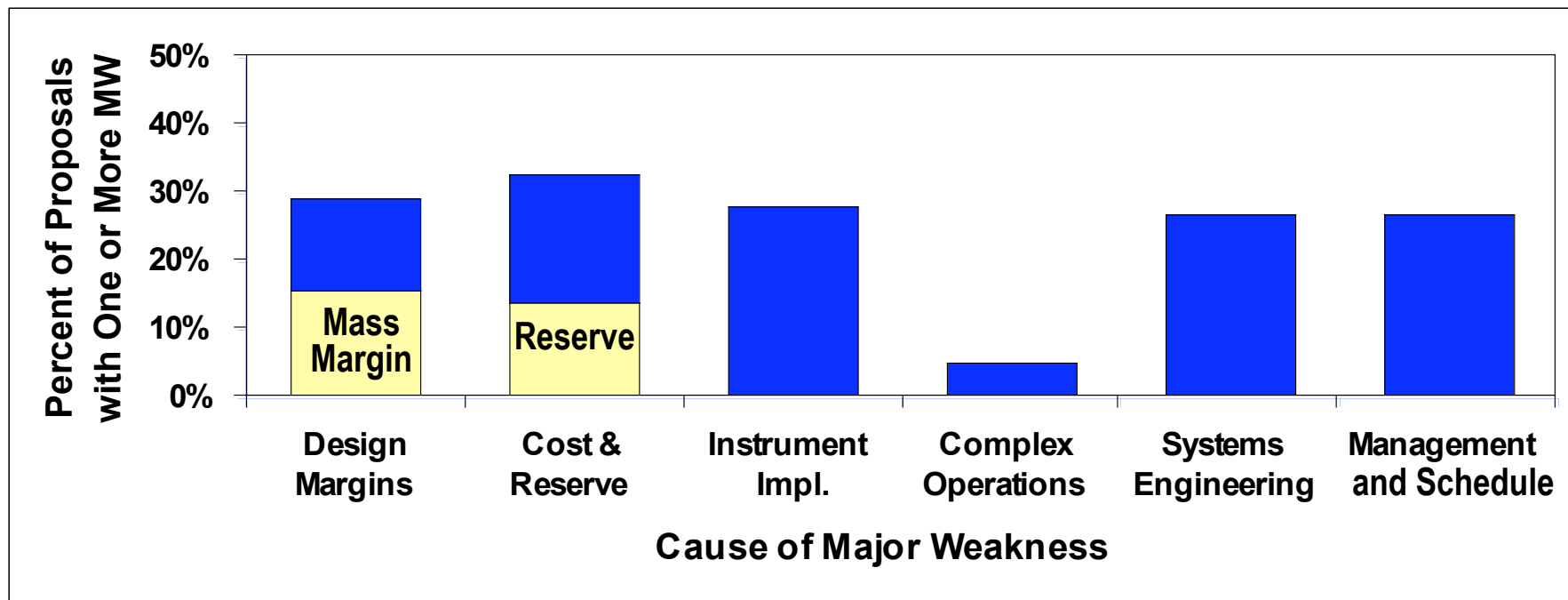


# Lessons Learned Summary

## Common Causes of Major Weaknesses

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Lessons Learned

- Common causes for Major Weaknesses can be categorized in six areas noted below.
- The figure also shows the percentage of Step 1 proposals with one or more identified Major Weaknesses in each of these categories.
- Two issues, mass margin and cost reserve, are highlighted for special attention since they are prominent as sources of many Major Weakness findings.





# Common Causes of Major Weaknesses Design Margins

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Lessons Learned

Mass and power margins were the most prevalent areas of concern:

Mass: Common reasons for Major Weaknesses:

1. Unable to verify the margin.
2. No mass margin was identified or the proposal contained conflicting statements.
3. Mass margins were too low based on the maturity of the proposed design, or required elements were omitted.
4. Confusion between mass contingency and mass margin.

The TMC review teams look for a competent engineering design that includes appropriate levels of contingency and margin, along with suitable rationale for the size of both.

Power: Common reasons for Major Weaknesses:

1. Margins were not calculated against the most critical or demanding operating mode.
2. Maneuver impulse budgets and propellant requirements could not be verified.
3. Could not verify and assess suitability of stated margins for both high-thrust and low-thrust propulsion systems.



# Common Causes of Major Weaknesses Cost and Reserves

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**Lessons Learned**

There are three common reasons why proposals received a cost Major Weakness:

1. Cost Reserve is too low.
  - A reserve level (percent of cost-to-go) is below the stated AO requirement.
  - Liens already identified against the reserves.
  - Reserves are too low to cover cost threats identified during evaluation.
  - Phasing of reserves in the funding profile is too late to be useful.
2. Basis of Estimate is flawed: Rationale and method is unconvincing or deficient.
3. Unable to validate proposer's cost estimate:
  - Multiple independent cost analyses are developed for each proposal.
  - A large uncertainty bar is added giving the benefit of doubt to the proposer.
  - A proposed cost that falls outside this cost range is likely to be flagged as a Major Weakness.



# Common Causes of Major Weaknesses Instrument Implementation

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**Lessons Learned**

Areas of concern that produce Major Weaknesses include:

1. Complex new designs for which the development risks are not adequately addressed.
2. Inadequate or inconsistent description and detail that preclude a reasonable TMC evaluation.
3. Weak heritage claims.
4. Inconsistencies between instrument requirements and the spacecraft instrument accommodation capabilities.
5. Insufficient integration and test program including an end-to-end verification test.
6. Issues with pointing performance (knowledge, accuracy, etc.) and potential for detector contamination during flight.



# Common Causes of Major Weaknesses Complex Operations

**TMC**  
**Lessons Learned**

Major Weaknesses related to the complexity of the proposed operations included:

1. Complex observing sequences for instruments:
  - For payloads consisting of several instruments that must be operated sequentially.
  - Where many critical events must occur in a short period of time.
2. Proposed landers that present additional operational challenges that may not be adequately planned.
3. Concept of operations not clearly defined and inadequate or incomplete explanation of how the operations planning will be developed and tested.



# Common Causes of Major Weaknesses Systems Engineering

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Major Weaknesses for Systems Engineering seem to occur more often in earlier proposals. Recent experience seems to indicate an improvement in the number of Major Weaknesses in this area, perhaps in response to firm AO requirements for a traceability matrix to flow down science requirements to instruments, payload accommodations and flight systems.

More recent concerns that continue to produce Major Weaknesses in systems engineering are:

1. Incomplete or unconvincing plan for how systems engineering responsibilities will be executed across the entire project.
2. Implementation plan not providing for adequate resources for all participating organizations to successfully accomplish this function.
3. Underestimates of the cost of this function.



# Common Causes of Major Weaknesses Management and Schedule

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**Lessons Learned**

The common causes of Major Weaknesses in project management are as follows.

1. Confusing organizational roles and responsibilities for the participating institutions or key individuals.
2. Unclear lines of authority within the project, or between the project and the participating institutions.
3. Lack of demonstrated organization or individual expertise for the specific role identified.
4. Low time commitments for essential members of the core management team.
5. Missing letters of commitment or endorsement from partners, as required by AO instruction.



# Common Causes of Major Weaknesses Management and Schedule (concluded)

**TMC**  
**Lessons Learned**

The common causes for Major Weaknesses in schedule are as follows:

1. Insufficient detail from which to perform a reasonable assessment of whether the proposer understands how all of the work will be accomplished in time.
2. The master schedule shows no margin or inadequate margin to address potential delays.
3. TMC assesses whether the proposed schedule reflects realistic expectations based on recent experiences in flight system and payload development. An area that receives special consideration is the plan for Assembly, Test, and Launch Operations (ATLO).



# Summary

## TMC Lessons Learned

- The results presented were derived from an analysis of all TMC proposal evaluation activity conducted by the SSO during the period 1996-2005.
- The TMC review team looks for evidence of thorough designs and robust plans in all aspects of the proposed technical, management, and cost considerations. The final judgment of how well the proposal meets this expectation is the Implementation Risk Rating, which is summarized as Low, Medium, or High Risk.
- The primary consideration that raises a proposal's Risk Rating from Low to Medium or High is the Major Weaknesses identified during the Step 1 proposal review. Not all Major Weaknesses are of equal importance: One serious issue may be enough to convince the TMC review team that Risk Rating is High.
- Review of the 10-year history of proposal evaluations conducted by the SSO identified six areas that are common causes of Major Weaknesses: 1) Design margins, 2) Cost issues, 3) Instrument implementation, 4) Complex operations, 5) Systems engineering, and 6) Management and Schedule Plans.

The goal of proposers should be to eliminate Major Weaknesses from their proposals.



# Questions

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Lessons Learned





# **Supplemental Information**



# TMC Key Technical Definitions

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- **Contingency (or Reserve):** When added to a resource, results in the maximum expected value for that resource. Percent contingency is the proposed value of the contingency divided by the maximum expected value of the resource minus the contingency.
- **Margin:** The difference between the maximum possible value of a resource (the physical limit or the agreed-to limit) and the maximum expected value for a resource. Percent margin for a resource is the margin divided by the maximum possible value minus the margin.
- **Example 1:** A payload in the design phase has an estimated mass of 115 kg including a proposed mass reserve of 15 kg. There is no other payload on the ELV and the ELV provider plans to allot the full capability of the vehicle, if needed. The ELV capability is 200 kg. The mass reserve is  $15/100 = 15\%$  and the mass margin is 85 kg or  $85/115 = 74\%$
- **Example 2:** The end-of-mission life capability of a spacecraft power system is 200 watts. The proposed instrument is expected to use 40 watts, and a 25% contingency is planned. If 75 watts is allotted by the satellite provider, the reserve is 10 watts and the margin is 25 watts, or  $25/50 = 50\%$



## Mission Categorization

An *ad hoc* subcommittee of the SMD AO Steering Committee composed wholly of Civil Servants and appointed by the Associate Administrator for the Science Mission Directorate, will convene to consider the peer review results and categorize the proposals in accordance with procedures required by NASA FAR Supplement Part 1872. The categories are defined as follows:

- **Category I.** Well conceived and scientifically and technically sound investigations pertinent to the goals of the program and the AO's objectives, and offered by a competent investigator from an institution capable of supplying the necessary support to ensure that any essential flight hardware or other support can be delivered on time, and that data can be properly reduced, analyzed, interpreted, and published in a reasonable time. Investigations in Category I are recommended for acceptance and normally will be displaced only by other Category I investigations.
- **Category II.** Well conceived and scientifically or technically sound investigations that are recommended for acceptance, but at a lower priority than Category I.
- **Category III.** Scientifically or technically sound investigations that require further development. Category III investigations may be funded for development and may be reconsidered at a later time for the same or other opportunities.
- **Category IV.** Proposed investigations which are recommended for rejection for the particular opportunity under consideration, whatever the reason.



# Definition: Step 1 Evaluations

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**Lessons Learned**

## **Step 1 Evaluations:** Evaluation of Proposals:

- The proposals contain all of the information that is evaluated and proposer feedback or the ability to ask the proposer questions is typically not allowed.
- TMC Panel Consensus Findings are reported as Major and Minor Strengths and Weaknesses.
- TMC Panel consensus is developed giving the benefit of reasonable doubt to the proposer.
- The final TMC evaluation product is a Form C with a Risk Rating as either Low, Medium, or High.
- Only Major Strengths and Major Weaknesses are considered in determining the overall Form C Risk Rating.
- The Form C Risk Rating is supported by a Form S, a Cost Assessment Summary. The Cost Assessment Summary also has a Risk Rating of: Low, Low-Medium, Medium, High-Medium, High.
- Selected proposals are allowed to continue to the Concept Study Stage (Step 2) where proposers are usually given approximately 6-7 months to produce a CSR.



## Definition: Step 2 Evaluations

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### Step 2 Evaluations - Evaluation of CSRs:

- In addition to the information contained in the CSRs, the TMC Evaluation Team is given the opportunity to ask the proposer questions:
  - Written Questions: Questions developed as Team Consensus and sent to proposer to answer either prior to a Site Visit or at the Site Visit.
  - Verbal Questions: Asked during the Site Visit presentation.
- TMC Panel Consensus Findings are reported as Major and Minor Strengths and Weaknesses.
- TMC Panel consensus is developed without giving the benefit of the doubt to the proposer.
- The final TMC evaluation product is a Form C with a Risk Rating as either Low, Medium, or High, each rating further resolved into three bins for a total of 9 bins.
- Both Major and Minor Strengths and Weaknesses are considered in determining the overall Form C Risk Rating.
- The Form C Risk Rating is supported by a Form S, a Cost Assessment Summary. The Cost Assessment Summary also has a Risk Rating of: Low, Low-Medium, Medium, High-Medium, High.
- Selected proposals are allowed to continue to Phase B.



# Definition:

## TMC Strengths and Weaknesses

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- **Major Strength:** A facet of the implementation response that is judged to be well above expectations and that can substantially contribute to the project's ability to meet its technical requirements on schedule and within cost.
- **Minor Strength:** A strength that is worthy of note and can be brought to the attention of proposers during debriefings, but is not a discriminator in the assessment of risk.
- **Major Weakness:** A deficiency, or set of deficiencies taken together, judged to substantially affect the proposer's ability to meet the technical objectives within the proposed cost and schedule.
- **Minor Weakness:** A weakness that is sufficiently worrisome to note and can be brought to the attention of proposers during debriefings, but is not a discriminator in the assessment of risk.



# Proposal Evaluation Criteria (Summary)

**TMC**  
**Lessons Learned**

The criteria used for evaluation are as follows:

- **Scientific merit of the investigation (Form A):** Accomplished by the Science Panel.
- **Technical merit and feasibility of the proposed investigation (Form B):**  
Accomplished by the Science Panel. The TMC Panel may provide input by providing comments to the Science Panel. In addition, the TMC Panel may provide Instrument Evaluation technical support to the Science Panel.
- **Feasibility of the proposed approach for mission implementation, including Cost Risk (Form C):** Evaluated by the TMC Evaluation Panel. This *may* also include New Technology/Technology Transfer, Small Disadvantaged Business (SDB), and Past Performance Evaluation.
- **Quality of plans for E/PO including implementation feasibility (Form D):** This is evaluated outside of the TMC Evaluation Panel.



# TMC Independent Cost Assessment Pyramid

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Lessons Learned

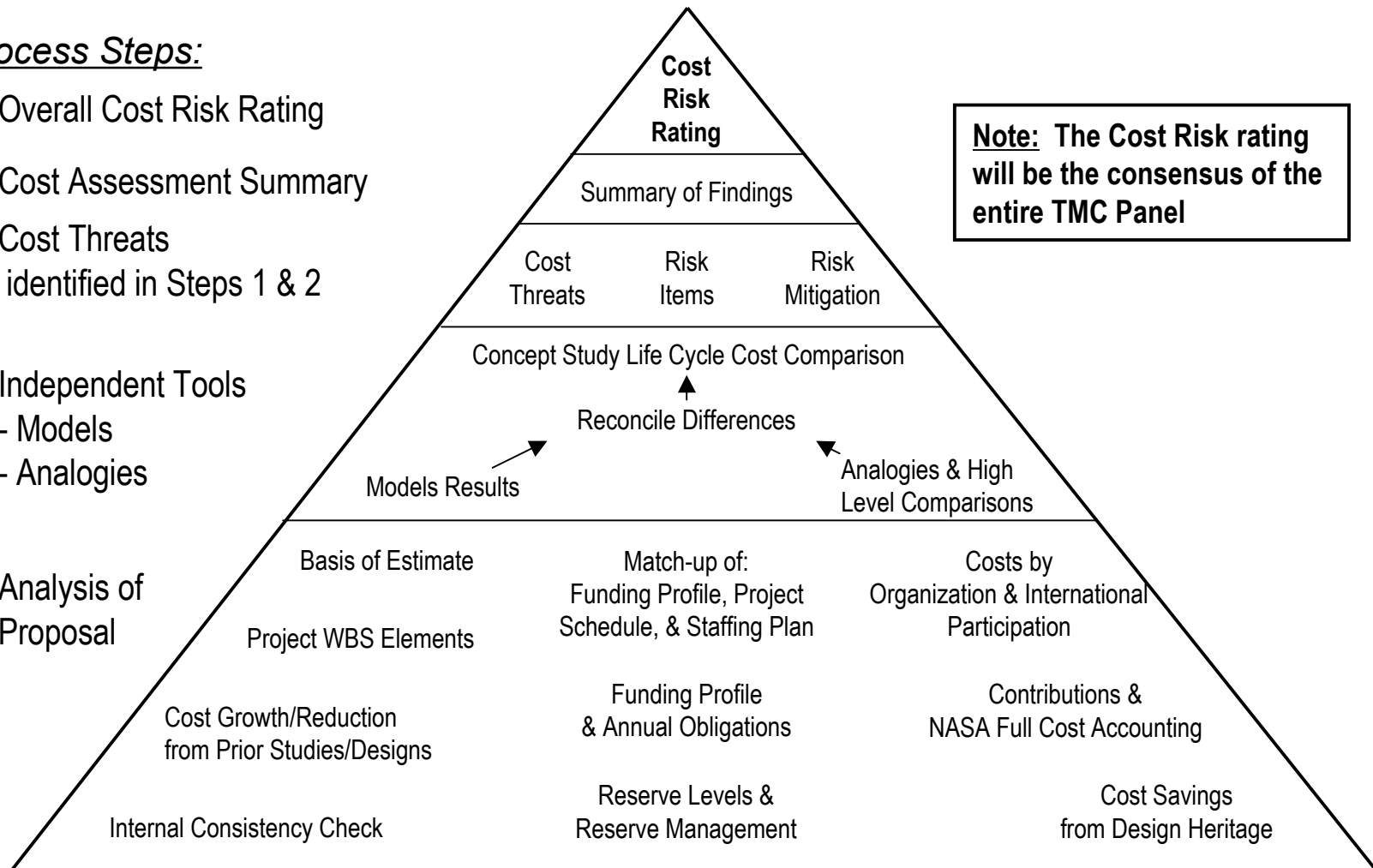
## ***“The Pyramid”***

### Process Steps:

5. Overall Cost Risk Rating
4. Cost Assessment Summary
3. Cost Threats identified in Steps 1 & 2

2. Independent Tools
  - Models
  - Analogies

1. Analysis of Proposal



**Note:** The Cost Risk rating will be the consensus of the entire TMC Panel



# TMC Evaluation Objective

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Lessons Learned

- The TMC evaluation is to determine, for each proposal, the level of risk of accomplishing the scientific objectives of the investigation, as proposed, on time and within cost.
- There are three possible Risk Levels: Low, Medium, and High
  - **Low Risk:** There are no problems in the proposal that cannot be normally solved within the time and cost proposed. Problems are not of sufficient magnitude to doubt the proposer's capability to accomplish the investigation. **"Envelope more than adequate"**
  - **Medium Risk:** Problems have been identified, but are considered within the proposal team's capabilities to correct with good management and application of effective engineering resources. Technology may not currently be ready, but available time and money should get it there or there is a viable mitigation. **"Envelope adequate but tight"**
  - **High Risk:** Problems are of sufficient magnitude such that implementation as proposed is highly improbable. **"Envelope inadequate"**



# Typical TMC Evaluation Questions to be Answered

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**Lessons Learned**

- Will overall mission/project design (spacecraft, launch vehicle, ground system, mission operation) allow successful implementation of mission as proposed? If not, are there sufficient resources (time & \$) to correct identified problems?
- Does proposed design/development allow the mission to have a reasonable probability of accomplishing its objectives and include all needed tools? Does it depend on new technology that has not yet been demonstrated? Are requirements within existing capabilities or are advances required? Does the proposal accommodate sufficient resiliency in appropriate resources (e.g., money, mass, power) to accommodate development uncertainties?
- Is there a Risk Management approach adequate to identify problems with sufficient warning to allow for mitigation without impacting the mission objectives? Does proposer understand their known risks and are there adequate fallback plans to mitigate them, including risk of using new technology, to assure that the mission can be completed as proposed?



# Typical TMC Evaluation Questions to be Answered (concluded)

**TMC**  
**Lessons Learned**

- Is the schedule doable? Does it reveal an understanding of the work to be done and the time it takes to do it? Is there a reasonable probability of launching on time? Does it include schedule margin?
- Will proposed management approach (e.g., institutions and personnel, as known, organization, roles and responsibilities, experience, commitment, performance measurement tools, decision process, etc.) allow successful completion of the mission? Is the PI in charge?
- Does the mission, as proposed, have a reasonable chance of being accomplished within proposed cost? Are proposed costs within appropriate caps and does cost estimate cover all costs including full-cost accounting for NASA Centers? Are costs phased reasonably? Is there evidence in the proposal to give confidence in the proposed cost? Does the proposer recognize all potential risks/threats for additional costs or cost growth?



# Step 1 Evaluation Ground Rules

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Lessons Learned

- All proposals are reviewed to identical standards and without comparison to other proposals.
- The Step One Selection is based primarily on Science.
- The Integrated TMC Risk Assessment is based on a *preliminary concept* with appropriate benefit of the doubt given to the proposer.
- Evaluators are peers in the areas of expertise they will be evaluating.
- All Evaluators verify the accuracy and completeness of findings throughout the entire process.
- TMC Findings will be the consensus of the entire TMC Panel.
- High Risk proposals will not be recommended for selection. Low risk, compelling science is very acceptable; medium risk, compelling science may also be acceptable.

Basic Assumption: Proposer is the expert on their proposal.

- TMC: Task is to try to validate proposer's assertion of Low Risk.
- Proposer: Task is to provide evidence that the project is Low Risk.



# Some Characteristics Applicable to a Low Risk Rating

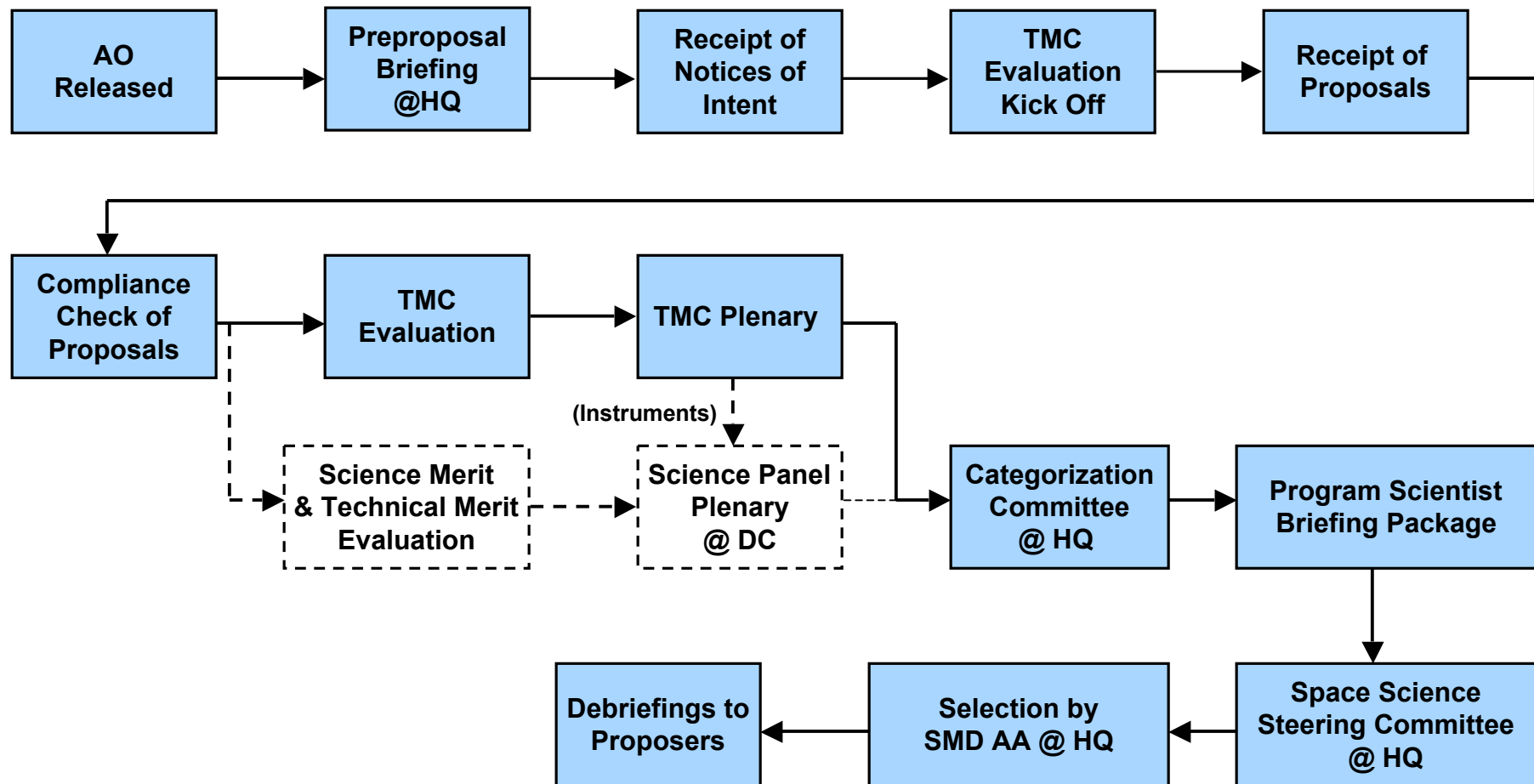
TMC  
Lessons Learned

- All risks for the project have been/are being identified and managed by the proposal team, with plans to reduce or retire the risk before launch.
- No risk exists for which there is neither a workaround planned, nor a very sound plan to develop and qualify the risk item for flight.
- The proposed Project Team and each of its critical participants are competent, qualified, and committed to execute the project.
- The project will be self managed to a successful conclusion while providing reasonable visibility to NASA for oversight.
- The proposal team has thoroughly analyzed all project requirements, and the resulting resources proposed are adequate to cover the projected needs, including an additional percentage for growth during the design and development, and then a margin on top of that for unforeseen difficulties.
- Reserve time exists in the schedule to find and fix problems if things do not go according to plan.
- Any contributed assets for the project are backed by letters of commitment.
- The proposal team understands the seriousness of failing to meet technical, schedule, or cost commitments for the project in today's environment.



# TMC Proposal Evaluation Process

**TMC**  
Lessons Learned





## Definition: Step 1 TMC Weaknesses

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Lessons Learned

- **Minor Weakness:** A weakness that is sufficiently worrisome to note and can be brought to the attention of proposers during debriefings, but is not a discriminator in the assessment of risk.
- **Major Weakness:** A deficiency, or set of deficiencies taken together, judged to substantially affect the proposer's ability to meet the technical objectives within the proposed cost and schedule.
  - Major Weaknesses as well as Major Strengths are a discriminator in the assessment of risk. Minor Weaknesses and Strengths are not a discriminator in the assessment of risk.
  - It is not the number of Major Weakness that convinces the TMC evaluation team that a proposal is High Risk. There are two items that are considered when judging Major Weaknesses:
    1. How serious is the Major Weakness?
    2. Can the Major Weakness be fixed within the budgeted cost cap and within schedule limitations?
  - One Major Weakness, if serious enough, could warrant a proposal to be judged to be High Risk.